THE NEEL COMPANY

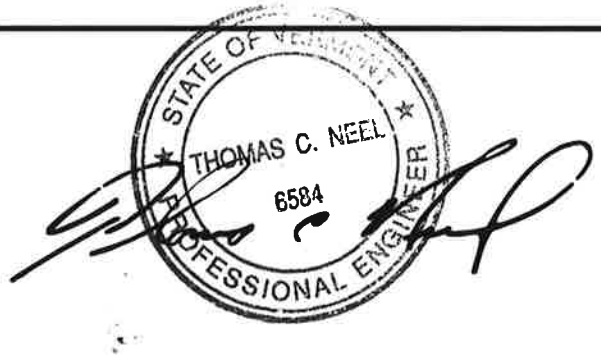
TW4437
2/9/15

T-WALL®

RETAINING WALL SYSTEM

LRFD STRUCTURAL DESIGN CALCULATIONS FOR 5. FT WIDE 5.50' HIGH TOP UNITS 6.00' HIGH TOP UNITS 6.50' HIGH TOP UNITS

T-WALL PRECAST UNITS



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T-WALL Rebar Summary Table (TOP UNITS):

In the table below:

H X W X Hstem = HEIGHT (FRONT FACE) X WIDTH X STEM HEIGHT

Only the calculations for the shaded T-wall top units are considered in this package for clarity

Top Units HxWxHstem	H-1 Bars	TB-1 Bars	V-2 Bars	S-1 Bars	Concrete (ksi)
STD TOP UNITS					
5.0x5.0x2.5	6, #4	4, #5	6, #5	4, #3	5
5.5x5.0x2.5	6, #4	4, #5	6, #5	4, #3	5
6.0x5.0x2.5	6, #4	4, #5	6, #5	4, #3	5
6.5x5.0x2.5	7, #4	4, #5	6, #5	4, #3	5

Notes:

the number of H-1 Bars for Top units can vary

Notes

1. The calculations comply with:

   AASHTO LRFD Bridge Design Specifications 2012

   The following is a list of the referenced information in the calculations.

   Loads: Per AASHTO Section 3

   Load factors: Per AASHTO Section 3, Table 3.4.1-1

   Resistance factors: Per AASHTO Section 5.5.4.2

   Flexural design: Per AASHTO Section 5.7.3.2

   Minimum reinforcement design: Per AASHTO Section 5.7.3.3.2

   Maximum reinforcement design: Per AASHTO Section 5.7.3.3.1

   Shear design: Per AASHTO Section 5.8.3

   Service design: Per AASHTO Section 5.7.3.4

   Temperature steel requirement design for face and stem: Per AASHTO Section 5.10.8.2

2. T-WALL® units are designed for the following backslope cases:

   Case I: Broken BackSlope And Traffic Surcharge,
   No traffic barrier and moment slab,
   240 psf traffic surcharge
   Ka = 0.3109 (see Page 4)

PER AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

Project No: TW4437 **Date:** 2/9/15
Project Name: I-89 Bridge Decks Rep. **Designed By:** KB
Comments: Backslope Case I: 1.5H:1V broken backslope, max. H = 11.5' **Checked By:** KD

GRADING GEOMETRY

Distance to slope		0	ft	
Slope height		3.75	ft	
Slope horizontal length		5	ft	
Angle of slope (β')	=	36.9	deg	
Slope angle (i)	=	9.3	deg	(B in AASHTO Fig. 3.11.5.8.1-3)
Wall height at the front face	h =	11.5	ft	

BACKFILL SPECIFICATIONS

Internal friction	ø =	34	deg	
Unit weight	γ =	120	pcf	
Earth pressure coefficient	Ka =	0.3109		(Per AASHTO Eq. 3.11.5.3-2)

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Rep.	Checked by:	KD	2/9/15

Pressure on T-WALL® Front Face - Static Cases

Backslope Case I: Broken backslope and Traffic Surcharge

γ =	120	pcf
ø =	34	deg.
Ka =	0.3109	
Ka * γ =	37.308	psf/ft

Earth Pressure = Ka * γ * h

Live Load surharge = Ka * 240 psf

	h (ft)	Earth Pressure (EH) (psf)	Live Load Surcharge (LS) (psf)	STRENGTH-I 1.5EH+1.75LS (psf)	SERVICE-I 1.0EH+1.0LS (psf)
Top of wall	0	0	75	131	75
Top of TOP unit	2.5	93	75	270	168
Bottom of 5.0' high TOP unit	7.5	280	75	550	354
Bottom of 6.0' high TOP unit	8.5	317	75	606	392
Bottom of 7.0' high TOP unit	9.5	354	75	662	429

Note: h=2.5' is the top of TOP unit

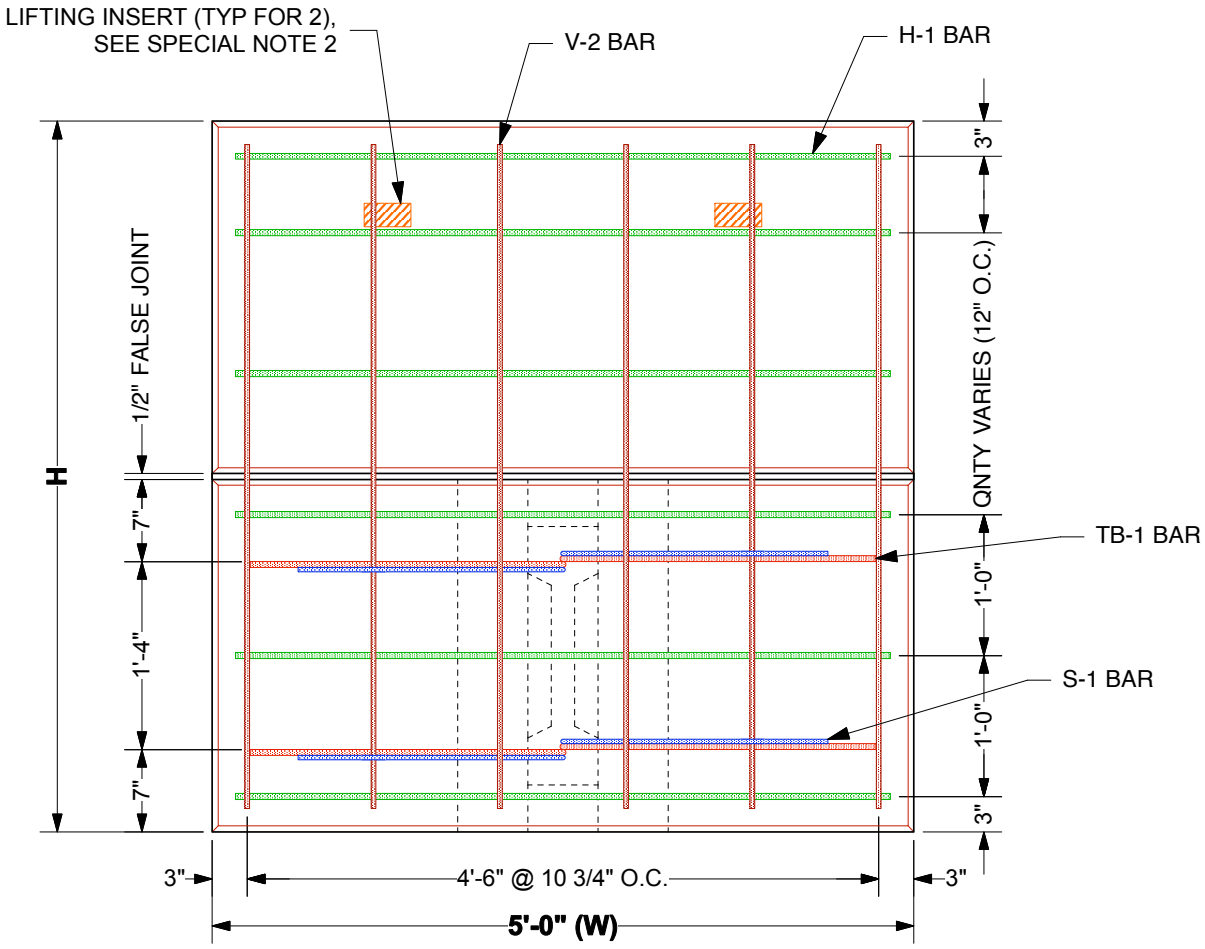
Structural Calculations
STD 5.5’ High Top Units

Loading: Slope Condition with Traffic Surcharge

Select Backfill Parameters:
Ø = 34º, γ = 120 pcf, Ka = 0.3109
Traffic Surcharge = 240 psf

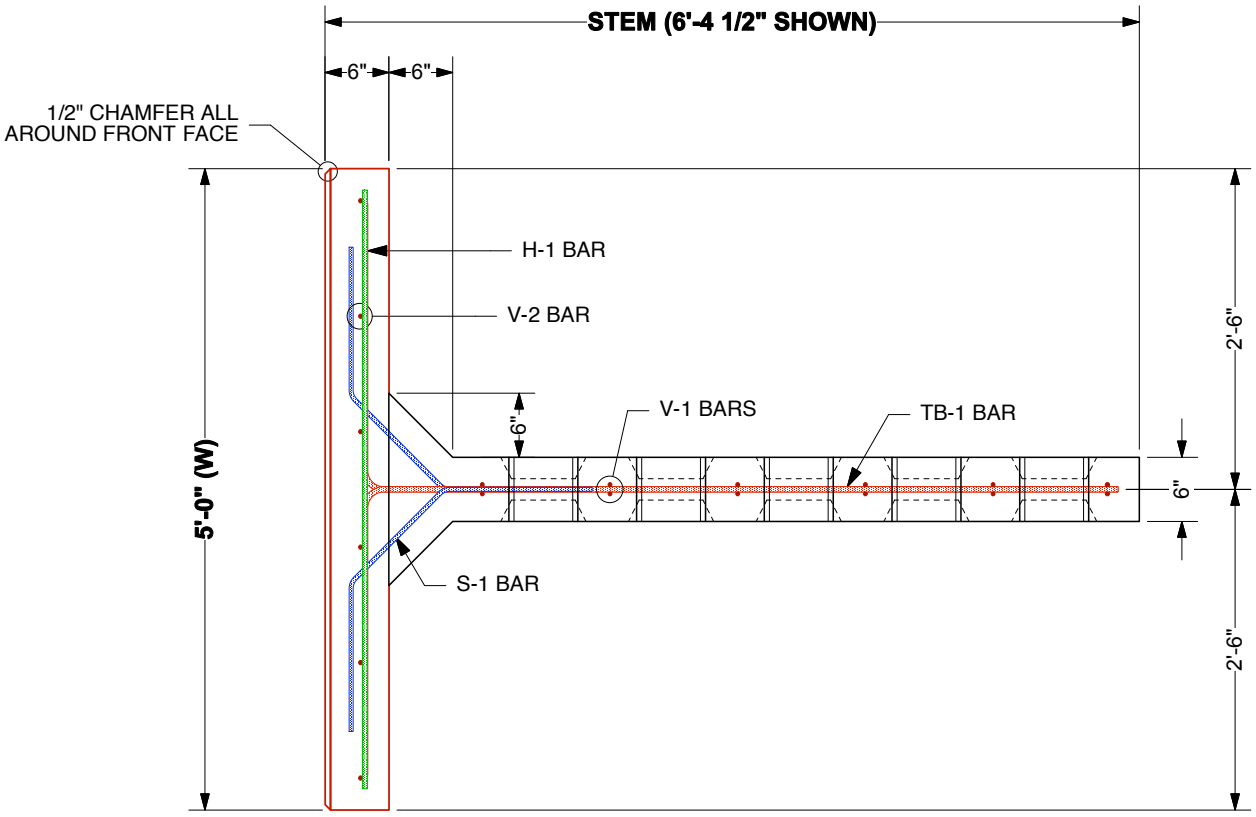
1. 5.5 x 5.0 x 2.5 (Face Height x Width x Stem Height)

Project No.: TW4437 Calculated by: KB 02/09/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 02/09/15
Note: STD TOP UNIT

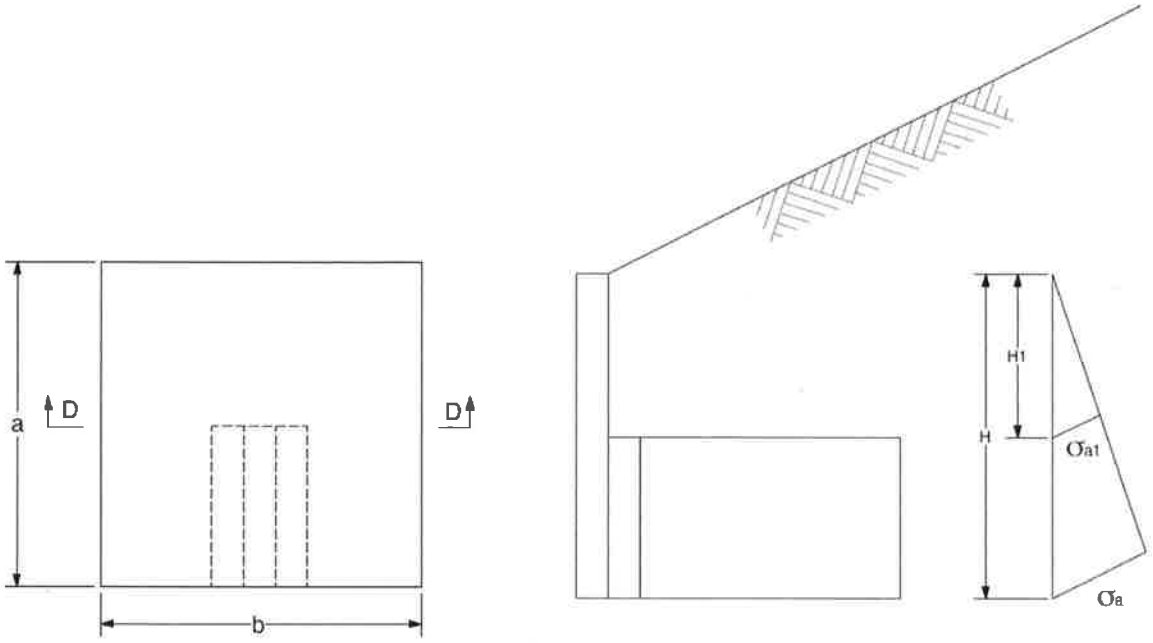


FRONT VIEW (STD TOP UNIT)

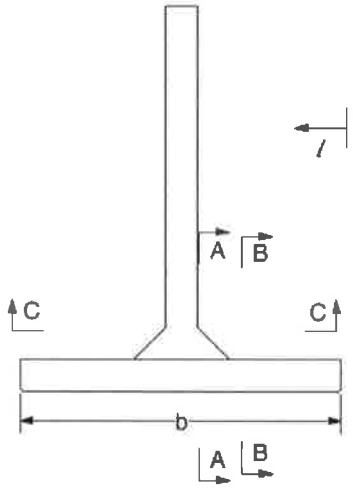
Project No.:	TW4437	Calculated by:	KB	02/09/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	02/09/15
Note:	STD TOP UNIT			



TOP VIEW (STD TOP UNIT)



FRONT VIEW **SECTION VIEW**



TOP VIEW

FIGURE 11 TOP UNIT
NOT TO SCALE

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	5.5'(H) x 5'(W) x 6'(Stem) top Unit, Slope Condition and traffic surcharge			

Design Parameters

Unit weight (γ) =	120	pcf
Friction Angle (ø) =	34	degrees
Earth pressure coefficient (Ka) =	0.311	See Page 4
Ka * γ =	37.3	
Ka =	0.311	
Traffic surchage (q_t) =	240	psf
Height of unit a =	5.5	ft
Width of front face b =	5	ft
Height of stem Hs =	2.5	ft
Thickness of stem ts =	0.5	ft
From grade to top of unit H_2 =	0	ft
From grade to bottom of unit H =	5.5	ft
From top of unit to top of stem H_1 =	3	ft
Havg = H-a/2 =	2.75	ft

Unfactored forces due to earth pressure (EH)

σ_{aavg} = ka γ Havg =	102.60	psf
σ_{a1} = K_a γ (H_1+H_2) =	111.92	psf
σ_{a2} = K_a γ H_2 =	0.00	psf
σ_a = K_a γ H =	205.19	psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment	M_a = 0.5 a σ_{aavg} l^2 =	1428.34	lbs*ft
	=	17.14	kips*in.
Shear	V_a = a σ_{aavg} l =	1269.64	lbs
	=	1.27	kips.

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Section B-B

Cantilever span (l) = 1.75 ft

Moment

$M_a = 0.5\ a\ \sigma_{aavg}\ l^2$ = 864.06 lbs*ft
= 10.37 kips*in.

Shear

$V_a = a\ \sigma_{aavg}\ l$ = 987.50 lbs
= 0.99 kips

Section C-C

Tension

$T_a = \sigma_{aavg}\ (a\ b - Hs\ ts)$ = 2.69 kips

Moment

$M_a = \sigma_{a2}\ (a\ b - Hs\ ts)(a/2 - Hs/2) +$
$0.5(\sigma_a - \sigma_{a2})(a\ b - Hs\ ts)(a/3 - Hs/2)$ = 1.57 kips*ft
= 18.85 kips*in

Section D-D

Moment

$M_a = b\ \sigma_{a2}\ H_1^2/2 + 0.5\ b\ (\sigma_{a1} - \sigma_{a2})\ H_1^2/3$ = 839.43 lbs*ft
= 10.07 kips*in.

Shear

$V_a = b\ (\sigma_{a1} + \sigma_{a2})\ H_1/2$ = 839.43 lbs
= 0.84 kips.

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Unfactored forces due to traffic surcharge (LS)

$\sigma_t = K_a\, q_t =$ 74.62 psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 1038.79 lbs*ft
= 12.47 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 923.37 lbs
= 0.92 kips

Section B-B

Cantilever span (l) = 1.75 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 628.41 lbs*ft
= 7.54 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 718.18 lbs
= 0.72 kips

Section C-C

Tension $T_t = \sigma_t\, (a\, b - Hs\, ts) =$ 1.96 kips

Moment $M_t = T_t\, (a/2 - Hs/2) =$ 2.94 kips*ft
35.26 kips*in

Section D-D

Moment $M_t = b\, \sigma_t\, H_1^2/2 =$ 1678.86 lbs*ft
= 20.15 kips*in.

Shear $V_t = b\, \sigma_t\, H_1 =$ 1119.24 lbs
= 1.12 kips

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	5.5'(H) x 5'(W) x 6'(Stem) top Unit, Section A-A			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	17.14	1.50	25.71	kips*in.
Traffic Surcharge LS	12.47	1.75	21.81	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	29.61	*Mu* =	47.52	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.27	1.50	1.90	kips
Traffic Surcharge LS	0.92	1.75	1.62	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	3.52	kips

Section parameters

b =	66	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90	
Factored *Mu* =	47.52	kips*in.
Bar Qnty & Size =	4, #4 + 2, #5	(4 of 6 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)
ρ =	0.00574	
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	275.90	(kips*in.)
øMn >= Mu	OK	

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	255.02	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.42	in^2	
Actually, Use	4, #4 + 2, #5	As = 1.42	in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so, ß1=	0.8
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.38 in.
c/d =	0.10	<=0.42, OK	

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	3.52	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	66.00	in.	
dv = Mn/(Asfy) =	3.60	in.	
0.25*fc'*bv*dv =	296.85	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	33.56	kips	
Shear reinforcement Av =	0.22	in^2	(2, #3 S-1 bar)
α =	45.00	deg.	
Vs = Av*fy*sin(α) =	9.33	kips	
øVn = ø * min(Vc+Vs,0.25*fc'*bv*dv) =	38.60	kips	
>= *Vu*		OK	

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	29.61	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0057	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.91	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	6.09	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.25	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.86		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	57.41	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	
Actually, rebar spacing =	11.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	5.5'(H) x 5'(W) x 6'(Stem) top Unit, Section B-B			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	10.37	1.50	15.55	kips*in.
Traffic Surcharge LS	7.54	1.75	13.20	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	17.91	*Mu* =	28.75	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	0.99	1.50	1.48	kips
Traffic Surcharge LS	0.72	1.75	1.26	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	2.74	kips

Section parameters

b =	66	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90		
Factored *Mu* =	28.75	kips*in.	
Bar Qnty & Size =	4, #4 + 2, #5		(4 of 6 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)	
ρ =	0.00574		
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	275.90	(kips*in.)	
øMn >= Mu	OK		

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	255.02	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.42	in^2	
Actually, Use	4, #4 + 2, #5	As =	1.42 in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so,	ß1=	0.8
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.38	in.
c/d =	0.10	<=0.42, OK		

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	2.74	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	66.00	in.	
dv = Mn/(Asfy) =	3.60	in.	
0.25*fc'*bv*dv =	296.85	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	33.56	kips	
øVn = ø * min(Vc,0.25*fc'*bv*dv) =	30.20	kips	>= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE	(a) 0.5*øVc =	15.10	kips >= Vu
TRUE	(b) The analyzed member is a slab, footing, or culvert		

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	17.91	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0057	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.91	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	3.68	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.25	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.86		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	97.84	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	11.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.: TW4437
Project Name: I-89 Bridge Decks Replacement
Note: 5.5'(H) x 5'(W) x 6'(Stem) top Unit, Section C-C

Calculated by: KB 2/9/15
Checked by: KD 2/9/15

Load combination - STRENGTH I

Tension

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	2.69	1.5	4.04	kips
Traffic Surcharge LS	1.96	1.75	3.43	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total) *T* =	4.65	Tu =	7.47	kips

Moment

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	18.85	1.5	28.28	kips*in
Traffic Surcharge LS	35.26	1.75	61.70	kips*in
Collision force	#N/A	#N/A	0.00	kips*in
Loads 4	#N/A	#N/A	0.00	kips*in
Loads 5	#N/A	#N/A	0.00	kips*in
(Total) *M* =	54.11	Mu =	89.98	kips*in

Section parameters

b =	6	in.	
h =	22	in.	h is the overall depth minus blockouts
d =	19	in.	
fc =	5	ksi	
fy =	60	ksi	

Strength Check - Moment & Tension Interaction

Resistance factor ø =	0.90	
Factored Tu =	7.47	kips
Factored Mu =	89.98	kips*in
# no. of layers of rebar =	2	
Bars / ea. layer =	2, #5	
As / ea. layer =	0.62	(in.^2)
ρ =	0.00544	
To=ø fy (#As) =	66.96	kips
Mo=øMn=ø As fy d(1-ρ fy/(1.7fc'))=	611.70	kips*in.

Is (Tu, Mu) inside the P-M Interaction Diagram? TRUE

Strength is OK

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Use superposition to compute tensile stress approximately.

Tension at service limit state T =	4.65	kips	
Tensile stress by tension fs1 = T/(#As) =	3.75	ksi	
Moment at service limit state M =	54.11	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0054	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.92	(dimensionless)	
Tensile stress by moment fs2 = M/(As*j*d) =	5.02	ksi	
Total tensile steel stress fss = fs1+fs2 =	8.77	ksi	
Exposure Class =	1		
γ_e =	1.00		
dc =	3.0	in.	Use min. concrete cover)
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.23		
s_{max} = 700 γ_e / ($ß_s$ f_{ss}) - 2dc =	59.12	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	16.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	5.5'(H) x 5'(W) x 6'(Stem) top Unit, Section D-D			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	10.07	1.50	15.11	kips*in.
Traffic Surcharge LS	20.15	1.75	35.26	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	30.22	*Mu* =	50.37	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	0.84	1.50	1.26	kips
Traffic Surcharge LS	1.12	1.75	1.96	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	3.22	kips

Section parameters

b =	60	in.	
h =	6	in.	h is the overall thickness
d =	3.19	in.	d=6-2-4/8-5/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90		
Factored *Mu* =	50.37	kips*in.	
Bar Qnty & Size =	6, #5	(6 V-2 bars)	
As =	1.86	(in.^2)	
ρ =	0.00972		
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	298.42	(kips*in.)	
øMn >= Mu	OK		

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	231.84	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.86	in^2	
Actually, Use	6, #5	As = 1.86	in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so, ß1=	0.8
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.55 in.
c/d =	0.17	<=0.42, OK	

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	3.22	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	60.00	in.	
dv = Mn/(Asfy) =	2.97	in.	
0.25*fc'*bv*dv =	222.84	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	25.19	kips	
øVn = ø * min(Vc,0.25*fc'*bv*dv) =	22.67	kips	>= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE	(a) 0.5*øVc =	11.34	kips >= Vu
TRUE	(b) The analyzed member is a slab, footing, or culvert		

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	30.22	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0097	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.89	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	5.71	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.81	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	2.26		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	48.66	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	10.60	in.	OK

Structural Calculations
STD 6.0’ High Top Units

Loading: Slope Condition with Traffic Surcharge

Select Backfill Parameters:
Ø = 34º, γ = 120 pcf, Ka = 0.3109
Traffic Surcharge = 240 psf

2. 6.0 x 5.0 x 2.5 (Face Height x Width x Stem Height)

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.0'(H) x 5'(W) x 6'(Stem) top Unit, Slope Condition and traffic surcharge			

Design Parameters

Unit weight (γ) =	120	pcf
Friction Angle (ø) =	34	degrees
Earth pressure coefficient (Ka) =	0.311	See page 4
Ka * γ =	37.3	psf/ft
Ka =	0.311	
Traffic surchage (q_t) =	240	psf
Height of unit a =	6	ft
Width of front face b =	5	ft
Height of stem Hs =	2.5	ft
Thickness of stem ts =	0.5	ft
From grade to top of unit H_2 =	0	ft
From grade to bottom of unit H =	6	ft
From top of unit to top of stem H_1 =	3.5	ft
Havg = H-a/2 =	3	ft

Unfactored forces due to earth pressure (EH)

σ_{aavg} = ka γ Havg =	111.92	psf
σ_{a1} = K_a γ (H_1+H_2) =	130.58	psf
σ_{a2} = K_a γ H_2 =	0.00	psf
σ_a = K_a γ H =	223.85	psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment	M_a = 0.5 a σ_{aavg} l^2 =	1699.85	lbs*ft
	=	20.40	kips*in.
Shear	V_a = a σ_{aavg} l =	1510.97	lbs
	=	1.51	kips.

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Section B-B

Cantilever span (l) = 1.75 ft

Moment $M_a = 0.5\ a\ \sigma_{aavg}\ l^2$ = 1028.30 lbs*ft
= 12.34 kips*in.

Shear $V_a = a\ \sigma_{aavg}\ l$ = 1175.20 lbs
= 1.18 kips

Section C-C

Tension $T_a = \sigma_{aavg}\ (a\ b - Hs\ ts)$ = 3.22 kips

Moment

$M_a = \sigma_{a2}\ (a\ b - Hs\ ts)(a/2 - Hs/2) +$
$0.5(\sigma_a - \sigma_{a2})(a\ b - Hs\ ts)(a/3 - Hs/2)$ = 2.41 kips*ft
= 28.96 kips*in

Section D-D

Moment

$M_a = b\ \sigma_{a2}\ H_1^2/2 + 0.5\ b\ (\sigma_{a1} - \sigma_{a2})\ H_1^2/3$ = 1332.98 lbs*ft
= 16.00 kips*in.

Shear

$V_a = b\ (\sigma_{a1} + \sigma_{a2})\ H_1/2$ = 1142.56 lbs
= 1.14 kips.

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Unfactored forces due to traffic surcharge (LS)

$\sigma_t = K_a\, q_t =$ 74.62 psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 1133.23 lbs*ft
= 13.60 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 1007.32 lbs
= 1.01 kips

Section B-B

Cantilever span (l) = 1.75 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 685.53 lbs*ft
= 8.23 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 783.47 lbs
= 0.78 kips

Section C-C

Tension $T_t = \sigma_t\, (a\, b - Hs\, ts) =$ 2.15 kips

Moment $M_t = T_t\, (a/2 - Hs/2) =$ 3.75 kips*ft
45.05 kips*in

Section D-D

Moment $M_t = b\, \sigma_t\, H_1^2/2 =$ 2285.12 lbs*ft
= 27.42 kips*in.

Shear $V_t = b\, \sigma_t\, H_1 =$ 1305.78 lbs
= 1.31 kips

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.0'(H) x 5'(W) x 6'(Stem) top Unit, Section A-A			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	20.40	1.50	30.60	kips*in.
Traffic Surcharge LS	13.60	1.75	23.80	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	34.00	*Mu* =	54.40	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.51	1.50	2.27	kips
Traffic Surcharge LS	1.01	1.75	1.76	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	4.03	kips

Section parameters

b =	60	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90	
Factored *Mu* =	54.40	kips*in.
Bar Qnty & Size =	4, #4 + 2, #5	(4 of 6 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)
ρ =	0.00631	
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	274.74	(kips*in.)
øMn >= Mu	OK	

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	231.84	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.42	in^2	
Actually, Use	4, #4 + 2, #5	As =	1.42 in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so, ß1=	0.8
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.42 in.
c/d =	0.11	<=0.42, OK	

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	4.03	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	60.00	in.	
dv = Mn/(Asfy) =	3.58	in.	
0.25*fc'*bv*dv =	268.72	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	30.38	kips	
Shear reinforcement Av =	0.22	in^2	(2, #3 S-1 bar)
α =	45.00	deg.	
Vs = Av*fy*sin(α) =	9.33	kips	
øVn = ø * min(Vc+Vs,0.25*fc'*bv*dv) =	35.74	kips	
>= *Vu*		OK	

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	34.00	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0063	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.91	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	7.02	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.25	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.86		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	49.20	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	
Actually, rebar spacing =	11.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.0'(H) x 5'(W) x 6'(Stem) top Unit, Section B-B			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	12.34	1.50	18.51	kips*in.
Traffic Surcharge LS	8.23	1.75	14.40	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	20.57	*Mu* =	32.91	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.18	1.50	1.76	kips
Traffic Surcharge LS	0.78	1.75	1.37	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	3.13	kips

Section parameters

b =	60	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90	
Factored *Mu* =	32.91	kips*in.
Bar Qnty & Size =	4, #4 + 2, #5	(4 of 6 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)
ρ =	0.00631	
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	274.74	(kips*in.)
øMn >= Mu	OK	

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	231.84	kips*in.
	øMn >1.2Mcr	
Therefore, As =	1.42	in^2
Actually, Use 4, #4 + 2, #5	As = 1.42	in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' = 5 ksi, so, ß1= 0.8

c = As*fy/(0.85*fc'*$ß_1$*b) = 0.42 in.

c/d = 0.11 <=0.42, OK

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	3.13	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	60.00	in.	
dv = Mn/(Asfy) =	3.58	in.	
0.25*fc'*bv*dv =	268.72	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	30.38	kips	
øVn = ø * min(Vc,0.25*fc'*bv*dv) =	27.34	kips	>= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE	(a) 0.5*øVc =	13.67	kips >= Vu
TRUE	(b) The analyzed member is a slab, footing, or culvert		

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	20.57	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0063	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.91	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	4.25	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.25	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.86		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	84.27	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	11.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15
Note: 6.0'(H) x 5'(W) x 6'(Stem) top Unit, Section C-C

Load combination - STRENGTH I

Tension

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	3.22	1.5	4.83	kips
Traffic Surcharge LS	2.15	1.75	3.75	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total) *T* =	5.36	Tu =	8.58	kips

Moment

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	28.96	1.5	43.44	kips*in
Traffic Surcharge LS	45.05	1.75	78.84	kips*in
Collision force	#N/A	#N/A	0.00	kips*in
Loads 4	#N/A	#N/A	0.00	kips*in
Loads 5	#N/A	#N/A	0.00	kips*in
(Total) *M* =	74.01	Mu =	122.28	kips*in

Section parameters

b =	6	in.	
h =	22	in.	h is the overall depth minus blockouts
d =	19	in.	
fc =	5	ksi	
fy =	60	ksi	

Strength Check - Moment & Tension Interaction

Resistance factor ø =	0.90	
Factored Tu =	8.58	kips
Factored Mu =	122.28	kips*in
# no. of layers of rebar =	2	
Bars / ea. layer =	2, #5	
As / ea. layer =	0.62	(in.^2)
ρ =	0.00544	
To=ø fy (#As) =	66.96	kips
Mo=øMn=ø As fy d(1-ρ fy/(1.7fc'))=	611.70	kips*in.

Is (Tu, Mu) inside the P-M Interaction Diagram? TRUE

Strength is OK

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Use superposition to compute tensile stress approximately.

Tension at service limit state T =	5.36	kips	
Tensile stress by tension fs1 = T/(#As) =	4.33	ksi	
Moment at service limit state M =	74.01	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0054	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.92	(dimensionless)	
Tensile stress by moment fs2 = M/(As*j*d) =	6.87	ksi	
Total tensile steel stress fss = fs1+fs2 =	11.19	ksi	
Exposure Class =	1		
γ_e =	1.00		
dc =	3.0	in.	Use min. concrete cover)
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.23		
s_{max} = 700 γ_e / ($ß_s$ f_{ss}) - 2dc =	45.04	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	16.00	in.	OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.0'(H) x 5'(W) x 6'(Stem) top Unit, Section D-D			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	16.00	1.50	23.99	kips*in.
Traffic Surcharge LS	27.42	1.75	47.99	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	43.42	*Mu* =	71.98	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.14	1.50	1.71	kips
Traffic Surcharge LS	1.31	1.75	2.29	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	4.00	kips

Section parameters

b =	60	in.	
h =	6	in.	h is the overall thickness
d =	3.19	in.	d=6-2-4/8-5/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90	
Factored *Mu* =	71.98	kips*in.
Bar Qnty & Size =	6, #5	(6 V-2 bars)
As =	1.86	(in.^2)
ρ =	0.00972	
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	298.42	(kips*in.)
øMn >= Mu	OK	

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	231.84	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.86	in^2	
Actually, Use	6, #5	As = 1.86	in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so, ß1=	0.8	
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.55	in.
c/d =	0.17	<=0.42, OK		

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	4.00	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	60.00	in.	
dv = Mn/(Asfy) =	2.97	in.	
0.25*fc'*bv*dv =	222.84	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	25.19	kips	
øVn = ø * min(Vc,0.25*fc'*bv*dv) =	22.67	kips	>= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE	(a) 0.5*øVc =	11.34	kips >= Vu
TRUE	(b) The analyzed member is a slab, footing, or culvert		

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	43.42	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0097	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.89	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	8.20	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.81	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	2.26		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	32.16	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	10.60	in.	OK

Structural Calculations
STD 6.5’ High Top Units

Loading: Slope Condition with Traffic Surcharge

Select Backfill Parameters:
Ø = 34º, γ = 120 pcf, Ka = 0.3109
Traffic Surcharge = 240 psf

3. 6.5 x 5.0 x 2.5 (Face Height x Width x Stem Height)

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.5'(H) x 5'(W) x 6'(Stem) top Unit, Slope Condition and traffic surcharge			

Design Parameters

Unit weight (γ) =	120	pcf
Friction Angle (ø) =	34	degrees
Earth pressure coefficient (Ka) =	0.311	See page 4
Ka * γ =	37.3	psf/ft
Ka =	0.311	
Traffic surchage (q_t) =	240	psf
Height of unit a =	6.5	ft
Width of front face b =	5	ft
Height of stem Hs =	2.5	ft
Thickness of stem ts =	0.5	ft
From grade to top of unit H_2 =	0	ft
From grade to bottom of unit H =	6.5	ft
From top of unit to top of stem H_1 =	4	ft
Havg = H-a/2 =	3.25	ft

Unfactored forces due to earth pressure (EH)

σ_{aavg} = ka γ Havg =	121.25	psf
σ_{a1} = K_a γ (H_1+H_2) =	149.23	psf
σ_{a2} = K_a γ H_2 =	0.00	psf
σ_a = K_a γ H =	242.50	psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment	M_a = 0.5 a σ_{aavg} l^2 =	1994.96	lbs*ft
	=	23.94	kips*in.
Shear	V_a = a σ_{aavg} l =	1773.30	lbs
	=	1.77	kips.

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Section B-B

Cantilever span (l) = 1.75 ft

Moment

$M_a = 0.5\ a\ \sigma_{aavg}\ l^2$ = 1206.83 lbs*ft
= 14.48 kips*in.

Shear

$V_a = a\ \sigma_{aavg}\ l$ = 1379.23 lbs
= 1.38 kips

Section C-C

Tension

$T_a = \sigma_{aavg}\ (a\ b - Hs\ ts)$ = 3.79 kips

Moment

$M_a = \sigma_{a2}\ (a\ b - Hs\ ts)(a/2 - Hs/2) +$
$0.5(\sigma_a - \sigma_{a2})(a\ b - Hs\ ts)(a/3 - Hs/2)$ = 3.47 kips*ft
= 41.68 kips*in

Section D-D

Moment

$M_a = b\ \sigma_{a2}\ H_1^2/2 + 0.5\ b\ (\sigma_{a1} - \sigma_{a2})\ H_1^2/3$ = 1989.76 lbs*ft
= 23.88 kips*in.

Shear

$V_a = b\ (\sigma_{a1} + \sigma_{a2})\ H_1/2$ = 1492.32 lbs
= 1.49 kips.

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Unfactored forces due to traffic surcharge (LS)

$\sigma_t = K_a\, q_t =$ 74.62 psf

Section A-A

Cantilever span (l) = 2.25 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 1227.67 lbs*ft
= 14.73 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 1091.26 lbs
= 1.09 kips

Section B-B

Cantilever span (l) = 1.75 ft

Moment $M_t = 0.5\, a\, \sigma_t\, l^2 =$ 742.66 lbs*ft
= 8.91 kips*in.

Shear $V_t = a\, \sigma_t\, l =$ 848.76 lbs
= 0.85 kips

Section C-C

Tension $T_t = \sigma_t\, (a\, b - Hs\, ts) =$ 2.33 kips

Moment $M_t = T_t\, (a/2 - Hs/2) =$ 4.66 kips*ft
55.96 kips*in

Section D-D

Moment $M_t = b\, \sigma_t\, H_1^2/2 =$ 2984.64 lbs*ft
= 35.82 kips*in.

Shear $V_t = b\, \sigma_t\, H_1 =$ 1492.32 lbs
= 1.49 kips

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Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.5'(H) x 5'(W) x 6'(Stem) top Unit, Section A-A			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	23.94	1.50	35.91	kips*in.
Traffic Surcharge LS	14.73	1.75	25.78	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	38.67	*Mu* =	61.69	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.77	1.50	2.66	kips
Traffic Surcharge LS	1.09	1.75	1.91	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	4.57	kips

Section parameters

b =	78	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90		
Factored *Mu* =	61.69	kips*in.	
Bar Qnty & Size =	4, #4 + 2, #5		(4 of 7 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)	
ρ =	0.00485		
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	277.70	(kips*in.)	
øMn >= Mu	OK		

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') = 0.536656315 ksi
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) = 301.39 kips*in.
øMn<=1.2Mcr, increase 33%
Therefore, As = 1.89 in^2
Actually, Use 4, #4 + 2, #5 As = 1.42 in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' = 5 ksi, so, ß1= 0.8
c = As*fy/(0.85*fc'*$ß_1$*b) = 0.32 in.
c/d = 0.09 <=0.42, OK

Shear Design

Resistance factor ø = 0.9
Factored *Vu* = 4.57 kips

Per AASHTO Article 5.8.3.4, ß = 2.00
bv = 78.00 in.
dv = Mn/(Asfy) = 3.62 in.
0.25*fc'*bv*dv = 353.10 kips
Vc=0.0316*ß*sqrt(fc')*bv*dv = 39.92 kips
Shear reinforcement Av = 0.22 in^2 (2, #3 S-1 bar)
α = 45.00 deg.
Vs = Av*fy*sin(α) = 9.33 kips
øVn = ø * min(Vc+Vs,0.25*fc'*bv*dv) = 44.33 kips
>= *Vu* OK

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M = 38.67 kips*in
Reinforcing ratio ρ = As/(bd) = 0.0049 (dimensionless)
Modulus ratio n = Es/Ec = 8 (dimensionless)
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 = 0.92 (dimensionless)
Steel tensile stress fss = M/(As*j*d) = 7.90 ksi

Exposure Class = 1
$γ_e$ = 1.00
dc = 2.25 in.
$ß_s$ = 1+dc/[0.7(h-dc)] = 1.86
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc = 43.21 in. (AASHTO 5.7.3.4-1)
s_{max} <= 24.00 in.

Actually, rebar spacing = 10.25 in. OK

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Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.5'(H) x 5'(W) x 6'(Stem) top Unit, Section B-B			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	14.48	1.50	21.72	kips*in.
Traffic Surcharge LS	8.91	1.75	15.60	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	23.39	*Mu* =	37.32	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.38	1.50	2.07	kips
Traffic Surcharge LS	0.85	1.75	1.49	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	3.55	kips

Section parameters

b =	78	in.	**Use the effective height for b**
h =	6	in.	h is the overall thickness
d =	3.75	in.	d=6-2-4/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90		
Factored *Mu* =	37.32	kips*in.	
Bar Qnty & Size =	4, #4 + 2, #5		(4 of 7 H-1 bars within effective height + 2 TB-1 bars)
As =	1.42	(in.^2)	
ρ =	0.00485		
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	277.70	(kips*in.)	
øMn >= Mu	OK		

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15

Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') = 0.536656315 ksi
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) = 301.39 kips*in.
øMn<=1.2Mcr, increase 33%
Therefore, As = 1.89 in^2
Actually, Use 4, #4 + 2, #5 As = 1.42 in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' = 5 ksi, so, ß1= 0.8
c = As*fy/(0.85*fc'*$ß_1$*b) = 0.32 in.
c/d = 0.09 <=0.42, OK

Shear Design

Resistance factor ø = 0.9
Factored *Vu* = 3.55 kips

Per AASHTO Article 5.8.3.4, ß = 2.00
bv = 78.00 in.
dv = Mn/(Asfy) = 3.62 in.
0.25*fc'*bv*dv = 353.10 kips
Vc=0.0316*ß*sqrt(fc')*bv*dv = 39.92 kips
øVn = ø * min(Vc,0.25*fc'*bv*dv) = 35.93 kips >= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE (a) 0.5*øVc = 17.96 kips >= Vu
TRUE (b) The analyzed member is a slab, footing, or culvert

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M = 23.39 kips*in
Reinforcing ratio ρ = As/(bd) = 0.0049 (dimensionless)
Modulus ratio n = Es/Ec = 8 (dimensionless)
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 = 0.92 (dimensionless)
Steel tensile stress fss = M/(As*j*d) = 4.78 ksi

Exposure Class = 1
$γ_e$ = 1.00
dc = 2.25 in.
$ß_s$ = 1+dc/[0.7(h-dc)] = 1.86
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc = 74.36 in. (AASHTO 5.7.3.4-1)
s_{max} <= 24.00 in. (DM4 5.10.3.2)

Actually, rebar spacing = 10.25 in. OK

T-WALL® Top Unit Spreadsheet for Highway v10.2 Revised BZY 6/3/2011

Project No.: TW4437 Calculated by: KB 2/9/15
Project Name: I-89 Bridge Decks Replacement Checked by: KD 2/9/15
Note: 6.5'(H) x 5'(W) x 6'(Stem) top Unit, Section C-C

Load combination - STRENGTH I

Tension

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	3.79	1.5	5.68	kips
Traffic Surcharge LS	2.33	1.75	4.08	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total) *T* =	6.12	Tu =	9.76	kips

Moment

	Unfactored T	Load factor	Factored T	
Earth Pressure EH	41.68	1.5	62.52	kips*in
Traffic Surcharge LS	55.96	1.75	97.93	kips*in
Collision force	#N/A	#N/A	0.00	kips*in
Loads 4	#N/A	#N/A	0.00	kips*in
Loads 5	#N/A	#N/A	0.00	kips*in
(Total) *M* =	97.64	Mu =	160.45	kips*in

Section parameters

b =	6	in.
h =	22	in.
d =	19	in.
fc =	5	ksi
fy =	60	ksi

h is the overall depth minus blockouts

Strength Check - Moment & Tension Interaction

Resistance factor ø =	0.90	
Factored Tu =	9.76	kips
Factored Mu =	160.45	kips*in
# no. of layers of rebar =	2	
Bars / ea. layer =	2, #5	
As / ea. layer =	0.62	(in.^2)
ρ =	0.00544	
To=ø fy (#As) =	66.96	kips
Mo=øMn=ø As fy d(1-ρ fy/(1.7fc'))=	611.70	kips*in.

Is (Tu, Mu) inside the P-M Interaction Diagram? TRUE

Strength is OK

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Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Use superposition to compute tensile stress approximately.

Tension at service limit state T =	6.12	kips	
Tensile stress by tension fs1 = T/(#As) =	4.94	ksi	
Moment at service limit state M =	97.64	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0054	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.92	(dimensionless)	
Tensile stress by moment fs2 = M/(As*j*d) =	9.06	ksi	
Total tensile steel stress fss = fs1+fs2 =	13.99	ksi	
Exposure Class =	1		
γ_e =	1.00		
dc =	3.0	in.	Use min. concrete cover)
$ß_s$ = 1+dc/[0.7(h-dc)] =	1.23		
s_{max} = 700 γ_e / ($ß_s$ f_{ss}) - 2dc =	34.82	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	16.00	in.	OK

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Project No.:	TW4437	Calculated by:	KB	2/9/15
Project Name:	I-89 Bridge Decks Replacement	Checked by:	KD	2/9/15
Note:	6.5'(H) x 5'(W) x 6'(Stem) top Unit, Section D-D			

Load combination - STRENGTH I

Moment

	Unfactored M	Load factor	Factored M	Units
Earth Pressure EH	23.88	1.50	35.82	kips*in.
Traffic Surcharge LS	35.82	1.75	62.68	kips*in.
Collision force	#N/A	#N/A	0.00	kips*in.
Loads 4	#N/A	#N/A	0.00	kips*in.
Loads 5	#N/A	#N/A	0.00	kips*in.
(Total) *M* =	59.69	*Mu* =	98.49	kips*in.

Shear

	Unfactored V	Load factor	Factored V	Units
Earth Pressure EH	1.49	1.50	2.24	kips
Traffic Surcharge LS	1.49	1.75	2.61	kips
Collision force	#N/A	#N/A	0.00	kips
Loads 4	#N/A	#N/A	0.00	kips
Loads 5	#N/A	#N/A	0.00	kips
(Total)		*Vu* =	4.85	kips

Section parameters

b =	60	in.	
h =	6	in.	h is the overall thickness
d =	3.19	in.	d=6-2-4/8-5/8/2
fc =	5	ksi	Concrete cover=2"
fy =	60	ksi	

Flexural Design

Resistance factor ø =	0.90	
Factored *Mu* =	98.49	kips*in.
Bar Qnty & Size =	6, #5	(6 V-2 bars)
As =	1.86	(in.^2)
ρ =	0.00972	
øMn=ø*As*fy*d(1-ρ*fy/(1.7fc')) =	298.42	(kips*in.)
øMn >= Mu	OK	

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Flexural Design (continued)

Check min. Reinforcement limit, Per AASHTO 5.7.3.3.2

fr = 0.24*sqrt(fc') =	0.536656315	ksi	
1.2 Mcr= 1.2 fr*S = 1.2 fr*(bh^2/6) =	231.84	kips*in.	
	øMn >1.2Mcr		
Therefore, As =	1.86	in^2	
Actually, Use	6, #5	As = 1.86	in^2

Check max. Reinforcement limit, Per AASHTO 5.7.3.3.1

fc' =	5	ksi, so, ß1=	0.8
c =	As*fy/(0.85*fc'*$ß_1$*b)	=	0.55 in.
c/d =	0.17	<=0.42, OK	

Shear Design

Resistance factor ø =	0.9		
Factored *Vu* =	4.85	kips	
Per AASHTO Article 5.8.3.4, ß =	2.00		
bv =	60.00	in.	
dv = Mn/(Asfy) =	2.97	in.	
0.25*fc'*bv*dv =	222.84	kips	
Vc=0.0316*ß*sqrt(fc')*bv*dv =	25.19	kips	
øVn = ø * min(Vc,0.25*fc'*bv*dv) =	22.67	kips	>= Vu, OK

Per AASHTO Article 5.8.2.4, No Transverse reinforcement is required if either of the following is true:

TRUE	(a) 0.5*øVc =	11.34	kips >= Vu
TRUE	(b) The analyzed member is a slab, footing, or culvert		

Crack Control by Distribution of Reinforcement (AASHTO 5.7.3.4)

Tensile stress at service limit state

Moment at service limit state M =	59.69	kips*in	
Reinforcing ratio ρ = As/(bd) =	0.0097	(dimensionless)	
Modulus ratio n = Es/Ec =	8	(dimensionless)	
Parameter j=1-(sqrt(2ρn+(ρn)^2)-ρn)/3 =	0.89	(dimensionless)	
Steel tensile stress fss = M/(As*j*d) =	11.28	ksi	
Exposure Class =	1		
$γ_e$ =	1.00		
dc =	2.81	in.	
$ß_s$ = 1+dc/[0.7(h-dc)] =	2.26		
s_{max} = 700 $γ_e$ / ($ß_s$ f_{ss}) - 2dc =	21.86	in.	(AASHTO 5.7.3.4-1)
s_{max} <=	24.00	in.	(DM4 5.10.3.2)
Actually, rebar spacing =	10.60	in.	OK